Remote-Site Ambient Ozone Data Summary, 2020

Regions 2 and 4, US Forest Service

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McClure Pass monitoring site, Gunnison NF

Executive Summary:

- Extreme and widespread wildfire behavior across the intermountain western US produced several periods of elevated ozone at all sites on the R2/R4 network. The most heavily impacted were sites in northern Utah and northern and eastern Colorado, primarily in late August. Southern sites were also impacted by smoke in early July.
- Sites in the Wasatch Front and Front Range were again the most affected, although the August ozone event produced an extended period (4-8 days) of ozone loading potentially hazardous to vegetation at all sites.
- State regulatory agencies are pursuing exceptions to the EPA's ozone NAAQS attainment adjudication related to the fires. All nonattainment areas identified by 2019 remain in nonattainment.
- Strong winds associated with two strong cold fronts in September and October exacerbated fire behavior and emissions. Behind the fronts, much cleaner, colder air and substantial precipitation followed which reduced ozone impacts.
- The long-term trend in surface ozone, outside of periods influenced by wildfire emissions, continues downward at most sites. Despite this, sites in the Front Range and Wasatch Front remain susceptible to vegetation impacts.
- Wildfires also impacted site access for operators, and hampered data completeness at some sites. Travel restrictions related to COVID-19 had only minor effects.

I. Changes in the Regulatory Environment

In November 2018, USEPA finalized guidelines and aspects of the regulatory climate surrounding the 2016 "exceptional events" rule (40 CFR 50.14(c)(3), USEPA 2018). These are natural atmospheric phenomena that result in significantly increased levels of "criteria" pollutants (those governed by the National Ambient Air Quality Standards, or NAAQS, which includes surface ozone). To qualify as exceptional, an event must result from some external factor beyond the control of regulatory agencies. Wildfires, prescribed fire, and stratospheric intrusions of ozone are among the exceptional events especially relevant to the R2/R4 monitoring area.

Action agencies (usually state air quality functions) are required to "demonstrate" an exceptional event by providing evidence to EPA that elevated criteria pollutants were caused by the event. If the EPA approves the demonstration, monitoring data are flagged in the EPA's database and excluded from NAAQS attainment adjudication. In addition, agencies must formulate plans to mitigate impacts of the exceptional events (e.g., CDPHE 2018 [DRAFT]).

Stratospheric intrusion is more common at high elevation sites (e.g., Knowlton et al. 2017) and thus is critical to analysis of ozone trends on the R2/R4 network. However, the demonstration process for stratospheric intrusion events is complex and involves data collection and analysis not currently feasible on most NFS lands. For the purposes of RMRS reporting, discussion of stratospheric intrusion will be limited to interpretation of CDPHE's demonstrations and their associated evaluation by USEPA. At the time of this report, CDPHE was planning to pursue a single demonstration in 2020 for the period of 21-27 August (G. Harshfield, CDPHE, pers. comm.). Data from this period will be excluded from ozone design value calculation (maximum daily 8-hour average, or MDA8 and will be reported separately.

USEPA have published guidance for designating wildfires as exceptional events (USEPA 2016). As with stratospheric intrusion, agencies must demonstrate that a wildfire was a causative event of elevated pollutant levels, and USEPA must evaluate the demonstration in order to flag data and exclude it from adjudication. Demonstrating wildfire impact is

somewhat simpler than for stratospheric intrusion. Agencies may use trajectory analysis (e.g., HYSPLIT), satellite smoke imagery, or data from PM and CO monitors to indicate impact of wildfire smoke. Monitoring assets for PM and CO do not exist near most locations of R2/R4 monitors; this report makes use of state-level demonstrations, fire and smoke mapping, and known wind patterns throughout the monitoring area.

Because RMRS ozone data are non-regulatory, no demonstrations will be submitted by RMRS.

II. Network Performance, Changes and Updates for 2020

No new sites were established or decomissioned. RMRS and NFS workers maintained a total of 19 sites. Data from all non-USFS maintained sites included in the 2019 report are again summarized this year. The data from the Canyonlands National Park CASTNet site have been added to the analyses.

Network-wide, data completeness was 87.2%, and 85.9% at USFS-managed sites. Instrument installation at Snowbird and Douglas Pass was delayed one month due to COVID-related travel restrictions. A planned early deployment at Ruby Guard was also delayed due to the tragic circumstances surrounding the murder of a Nevada Highway Patrol officer. Five sites experienced malfunctions that significantly affected data completeness:

At Douglas Pass, high winds knocked the solar panel off its mount and nearly blew the enclosure and instrumentation onto the ground. The site was completely rebuilt but was inoperative for about six weeks.

At Grand Mesa, battery failure affected data collection in late spring, and a malfunction related to the instrument's sample path scrubber occurred on July 11th. This malfunction was unfortunately not detected until QC of the data in late 2020, and no data after that date were usable.

The analyzer at the Deadman site ingested water during a storm in early June, which resulted in invalid data through mid-July.

Goliath Peak experienced a datalogger memory failure and all data after 27 August were lost.

The battery at Trout Creek Pass failed early in the year, but the site collected usable daytime data.

No significant modifications were made to the instruments for 2020 except for Ruby Guard. All equipment at Ruby Guard including the version 5.0 enclosure was replaced at the start of monitoring. The power-supply issues that have persisted there were eliminated, and a complete season of data was collected.

The Mullen, Cameron Peak, East Troublesome and Grizzly Creek fires complicated access to some Colorado sites. Kremmling and Deadman were the most affected, with no access in August and September.

Year-Round Sites	Forest	Begin Date	End Date	Data Completeness	Notes
Pawnee Buttes	PNG	1 Jan	31 Dec	91.5	
Briggsdale	PNG	1 Jan	31 Dec	97.4	
Kenosha Pass	PSINF	1 Jan	31 Dec	91.9	
Sunlight Mtn	WRNF	1 Jan	31 Dec	82.8	
Little Mtn	Ashley	1 Jan	31 Dec	99.5	
Centennial CASTNet	MBRNF	1 Jan	31 Dec	89.3	
RMNP CASTNet	RMNP	1 Jan	31 Dec	97.2	
Gothic CASTNet	GMUG	1 Jan	31 Dec	87.3	
Dinosaur NM CASTNet	NPS	1 Jan	31 Dec	96.0	
Shamrock	SNJF	1 Jan	31 Dec	91.9	
Mesa Verde CASTNet	NPS	1 Jan	31 Dec	99.3	
Canyonlands CASTNet	NPS	1 Jan	31 Dec	96.8	
GBNP CASTNet	NPS	1 Jan	31 Dec	98.4	
Seasonal Sites					
Deadman Pass	ARNF	4 Apr	6 Nov	70.9	Water ingestion, data loss
Goliath Pk	ARNF	27 May	27 Aug	70.1	Datalogger memory failure
Trout Cr Pass	PSINF	29 Apr	4 Oct	70.8	No overnight data
Kremmling	BLM	6 May	1 Dec	92.1	Access restricted due to fire
McClure Pass	GMUG	5 May	29 Sep	95.0	
Ripple Cr Pass	WRNF	29 May	29 Sep	97.0	
Grand Mesa	GMUG	4 May	11 Jul	39.9	Battery failure, analyzer failure
Norwood	SJNF	26 Mar	3 Oct	96.0	
Douglas Pass	BLM	3 May	30 Sep	44.6	Wind damage
Snowbird	WCNF	3 May	1 Oct	81.2	
Dark Canyon	MLSNF	30 Apr	2 Oct	98.3	
Ruby Guard	HTNF	2 May	1 Oct	97.8	

Table 1. 2020 Network performance

II. Data Summary:

	Average O_3 (ppb)		Daily 8-hour O_3 (ppb)***				Cumulative O_3 (ppm-hr)	
Year-Round Sites	**Daytime**	**Overnight**	**Max**	**Date**	**4th Max**	**Date**	**Max W126****	**Period**
Pawnee Buttes	44.3	37.3	63.7	22 Jul	62.8	27 Jun	11.0	Jun-Aug
Briggsdale	42.2	24.8	72.9	10 Jul	67.1	9 Aug	15.7	Jun-Aug
Kenosha Pass	52.1	47.9	73.4	7 Oct	71.8	14 Aug	15.3	Jun-Aug
Sunlight Mtn	48.7	48.3	68.4	14 Aug	64.7	17 Aug	9.9	Jul-Sep
Little Mtn	49.3	48.9	80.9	7 Sep	68.3	23 May	11.0	Jul-Sep
Centennial CASTNet	47.4	46.8	65.1	8 Aug	61.6	18 Apr	9.2	Jun-Aug
RMNP CASTNet	47.0	43.3	73.5	15 Jun	67.8	9 Jul	12.2	Jun-Aug
Gothic CASTNet	46.9	39.9	66.5	14 Aug	63.4	7 Sep	7.8	Jun-Aug
Dinosaur CASTNet	42.9	28.8	62.0	6 Jun	61.0	10 Jul	7.5	Jun-Aug
Shamrock	45.8	39.6	66.6	17 Jun	62.3	6 Jun	8.5	Apr-Jun
Mesa Verde CASTNet	46.4	43.7	67.0	7 Sep	64.6	10 May	10.0	Jul-Sep
Canyonlands CASTNet	43.6	41.8	66.0	10 Jul	61.5	14 Aug	8.8	Jun-Aug
GBNP CASTNet	45.5	43.6	72.8	9 Jul	66.3	7 Aug	11.4	Jun-Aug
Seasonal Sites								
Deadman Pass	52.5	51.8	80.6	29 May	67.9	7 Aug	14.1*	Aug-Oct
Goliath Pk	55.9	55.3	74.4	9 Jul	72.9	17 Jun	17.5**	Jun-Aug
Trout Cr Pass	50.3	46.6	71.0	7 Sep	65.6	14 Jun	9.0	Jun-Aug
Kremmling	44.8	23.5	67.0	23 May	65.4	5 May	8.1	Jun-Aug
McClure Pass	48.9	45.6	68.7	14 Aug	63.9	9 May	8.7	Jul-Sep
Ripple Cr Pass	51.2	49.9	68.9	8 Aug	64.0	14 Jun	12.1	Jul-Sep
Grand Mesa	46.6	48.3	64.6	18 May	62.6	22 May	*	*
Norwood	51.7	39.0	70.5	18 May	67.8	19 Aug	11.4	Apr-Jun
Douglas Pass	49.8	47.9	66.8	6 Sep	62.2	10 May	*	*
Snowbird	53.5	50.5	73.9	9 Jul	70.6	8 May	17.0**	Jul-Sep
Dark Canyon	50.3	43.0	65.8	7 Sep	64.4	10 May	10.7	Jul-Sep
Ruby Guard	48.4	42.6	63.7	29 Aug	61.8	8 Sep	9.9	Jul-Sep

Table 2: Summary statistics for all 2020 Sites. "Average O_3" is the mean of ozone readings between 8 a.m.-8 p.m. (Daytime) and 8 p.m.-8 a.m. (Overnight) for the entire growing season (April-September). "Daily 8-hour O_3" reports the days on which the highest and 4th-highest 8-hour averages were recorded (see text for further explanation). Values in red (over 70 ppb) are contributory to NAAQS exceedance.

*indicates site where missing data precluded complete assessment; actual peak may not have been observed. Deployment dates listed in Table 1.

**Statistic reflective of potential impact of long-term vegetation exposure; see text.

***Values of daily 8-hour maxima (MD8) for 21-27 August are excluded; see text.

III. Discussion:

The 2020 monitoring season was a year of fire and ice, and several unusual events common to all or nearly all of the network's sites highlighted what was otherwise a relatively benign year for ozone across the R2/R4 area. Extraordinary wildfire activity across the west, and especially in California, Utah and Colorado resulted in both acute and diffuse surface ozone impacts in summer and early autumn.

A series of electrical storms ignited numerous uncontrollable fires in northern California in mid-August, Effects of these fires were observed at every station on the network, though somewhat muted at the southernmost stations. Impacts from the California fire emissions were substantial across the intermountain west but were attenuated at times by easterly and northeasterly winds which tended to push the smoke seaward.

Though smaller than the California fire complexes, the very large wildfires in northern Colorado impacted ozone levels later in the year, especially in September and October. Higher ozone readings were recorded in those months at the network's eastern sites than at that time in past years.

Smaller fires in south-central Utah and eastern Nevada impacted some southern and western sites earlier in the season.

The fire season broke numerous records:

- At 1.76 million hectares, or about 4% of the state's total area, 2020 was the most destructive in the recorded history of California. The area burned is believed to be similar to that of an average pre-European settlement year (Stephens et al. 2007).
- The August Complex became California's largest fire on record, at 418,000 ha.
- Other very large fires (Creek, North Complex, LNU Lightning Complex, SCU Lightning Complex) ranked 3rd through 6th largest in California history, all of which exceeded 150,000 ha.
- Colorado's record for largest single fire (Hayman Fire, 2002), was broken in July by the Pine Gulch Fire and again later in the year by the Cameron Peak Fire, at 84,000 ha. The explosive East Troublesome fire also burned a larger area than Pine Gulch.
- Colorado's total area burned (269,000 ha, or about 1% of the state) was the largest on record.

On the 7th and 8th of September, a powerful arctic cold front passed through the region, dropping air temperatures precipitously and bringing snow at most sites. This front pushed a large volume of smoke-laden air before it and exacerbated fire behavior and emissions with high winds. The precipitation that followed stifled fire activity and lowered ozone levels after passage. The pre-frontal spike and subsequent drop in surface ozone is evident at every station, and the time of the front's passage can be pinpointed in each station's dataset.

A second, even colder weather event occurred in late October, which was evident in the datasets of the year-round monitoring stations. Pre-frontal winds again caused explosive, uncontrollable growth of already large fires in Colorado, particularly the Mullen, Cameron Peak and East Troublesome fires. This storm, which included overnight temperatures as low as -30C at some stations, also dropped as much as 40 cm of snow on the fire-affected areas and put an end to active fire behavior. Full containment of most fires was declared in November or early December.

Ozone behavior in 2020 can be better understood by examining the timeline of the fire events and frontal passages mentioned above (Fig. 1).

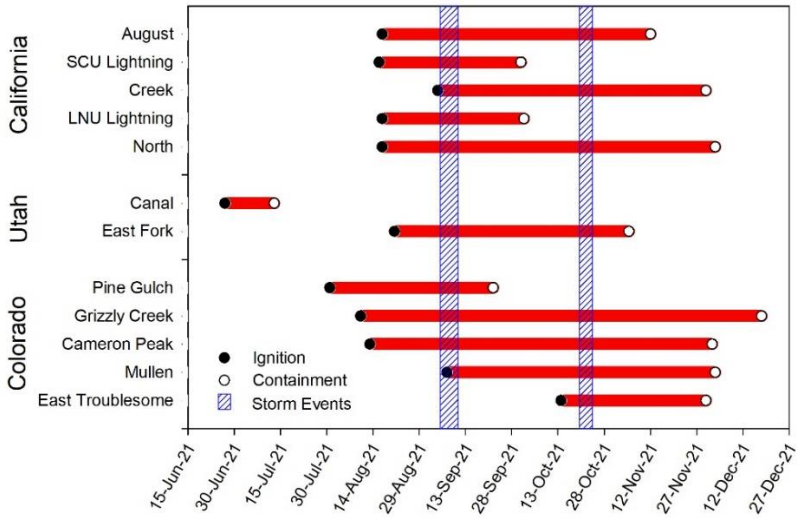

Figure 1. Timeline of selected 2020 wildfires in the western US.

USEPA criteria for ozone NAAQS nonattainment is determined by the design value (fourth-highest maximum daily 8-hour average ozone, or MDA8) for each year, and averaged over three years. The standard for this figure is 70 ppb. Table 3 presents the most recent three years of MDA8 and their averages. Table does not include data recorded 21-27 August.

Site	2018	2019	2020	3-Year Average
Pawnee Buttes	68.8	66.7	62.8	66.1
Briggsdale	70.3	72.8	67.1	70.1
Kenosha Pass	81.9	69.2	71.8	74.3
Sunlight Mtn	74.6	69.9	64.7	69.7
Little Mtn	74.6	71.6	68.3	71.5
Shamrock	71.7	59.6	62.3	64.5
Centennial CASTNet	70.0	65.0	61.6	65.5
RMNP CASTNet	74.1	65.6	67.8	69.2
Gothic CASTNet	69.3	66.4	63.4	66.4
GBNP CASTNet	71.1	66.5	66.3	68.0
Mesa Verde CASTNet	72.1	65.1	64.6	67.3
Dinosaur CASTNet	67.8	70.8	61.0	66.5
Canyonlands CASTNet			61.5	
Deadman Pass	75.0	63.6	67.9	68.8
Goliath Pk	84.0	69.7	72.9	75.5
Trout Cr Pass	72.6	65.9	65.6	68.0
Kremmling	67.3	60.8	65.4	64.5
McClure Pass	71.6	67.2	63.9	67.6
Ripple Cr Pass	72.1	55.4	64.0	63.8
Grand Mesa	67.3	65.5	62.6	65.1
Norwood	67.5	63.2	67.8	66.2
Douglas Pass	71.9	63.4	62.2	65.8
Snowbird	81.4	69.3	70.6	73.8
Dark Canyon	72.4	57.5	64.4	64.8
Ruby Guard	69.5	60.4	61.8	63.9

Table 3. Fourth-maximum daily values (MDA8) and three-year averages. Red indicates exceedance of NAAQS.

The extraordinary nature of wildfire behavior in 2020 induced state air quality agencies to argue for exceptions ("demonstrations") to the NAAQS. Excluding the high pollutant levels measured during wildfires provides a more realistic basis for assessing state-level efforts at mitigation. However, high ozone levels associated with fires still can potentially impact vegetation health. Every site on the RMRS network (except Little Mountain, UT) recorded their highest ozone values of the year during the California fire blowup phase of 20-27 August, and only one site (Shamrock, CO) did not reach an 8-hour average of 70 ppb. Table 4 provides the ozone figures applicable to vegetation health considerations. Potentially hazardous ozone loading (3-6 days of daytime ozone near or exceeding 60 ppb) occurred at nearly every site in 2020.

Site	Value (ppb)	Date of Peak	Duration of Event (hr)
Pawnee Buttes	80.2	24 Aug	102
Briggsdale	80.6	23 Aug	83
Kenosha Pass	90.8	22 Aug	103
Sunlight Mtn	79.3	22 Aug	115
Little Mtn	75.7	21 Aug	85
Shamrock	67.3	24 Aug	72
Centennial CASTNet	81.9	22 Aug	112
RMNP CASTNet	77.0	22 Aug	111
Gothic CASTNet	73.4	22 Aug	84
GBNP CASTNet	81.0	21 Aug	79
Mesa Verde CASTNet	78.0	21 Aug	126
Dinosaur CASTNet	72.0	22 Aug	77
Canyonlands CASTNet	73.6	21 Aug	118
Deadman Pass	83.1	22 Aug	156
Goliath Pk	86.2	22 Aug	173
Trout Cr Pass	71.6	22 Aug	96
Kremmling	74.9	23 Aug	79
McClure Pass	75.0	22 Aug	105
Ripple Cr Pass	85.5	22 Aug	112
Grand Mesa	No data	No data	No data
Norwood	81.1	21 Aug	152
Douglas Pass	83.5	21 Aug	113
Snowbird	81.5	21 Aug	207
Dark Canyon	76.0	22 Aug	126
Ruby Guard	93.1	22 Aug	84

Table 4. Maximum daily 8-hour values recorded during peak wildfire impact (21-28 August) and duration of the event.

IV. Funding.

Funds for this work are provided by Regions 2 and 4, USFS; the Ashley and Arapaho-Roosevelt NFs, and RMRS. A summary of funding is provided in Tables 5 and 6 below:

Source	Jobcode	Allocated, FY20	Expended	Balance, end FY20
Region 2	NFMG16	$30000	$28189	$1811
ARNF	NFVW10	$5000	$3540	$1538
Ashley NF	NFMP01	$1800	$1438	$362
RMRS	FRRESA	$11400	$11400	$0
Total		$48200	$44489	$3711

Table 5. Funding sources, expenditures and remaining balance, ozone data collection and analysis, FY20

The line for RMRS incorporates three pay periods of salary, an approximation of time needed to complete data QC and analyses.

Item	Amount	Percentage of Total
Salary	$27754	62
Travel	$4795	11
Vehicle Mileage	$4413	10
Parts/Equipment	$7604	17
Contract Repairs	$0	0
Contract Services	$0	0

Table 6. Expense categories and percentage of total expenditures, FY20

V. Acknowledgments:

RMRS personnel are grateful for the assistance of site operators Brian Murdock (Manti-LaSal NF), Helen Kempenich (retiree volunteer), Chris Plunkett, and Kevin Faucher (Ashley NF), and Andrea Holland (retiree volunteer). Their efforts result in increased efficiency of this project and considerable cost savings. RMRS also thanks Greg Harshfield, Clyde Sharp, and Bret Harkwell, Air Quality Division, CDPHE, for their efforts to conduct audits at many of the RMRS sites.

In May 2020, John Korfmacher of RMRS received the Paul Miller Award primarily for his work on the R2/R4 ozone network. He wishes to thank his site operators, especially the volunteers, for their efforts over the years, without which the work would not have been possible. He also thanks Bob Musselman, Kate Dwire, Jeff Sorkin, Linda Geiser and all members the National Air Program for their comradeship and guidance over the past fifteen years.

VI. Literature Cited:

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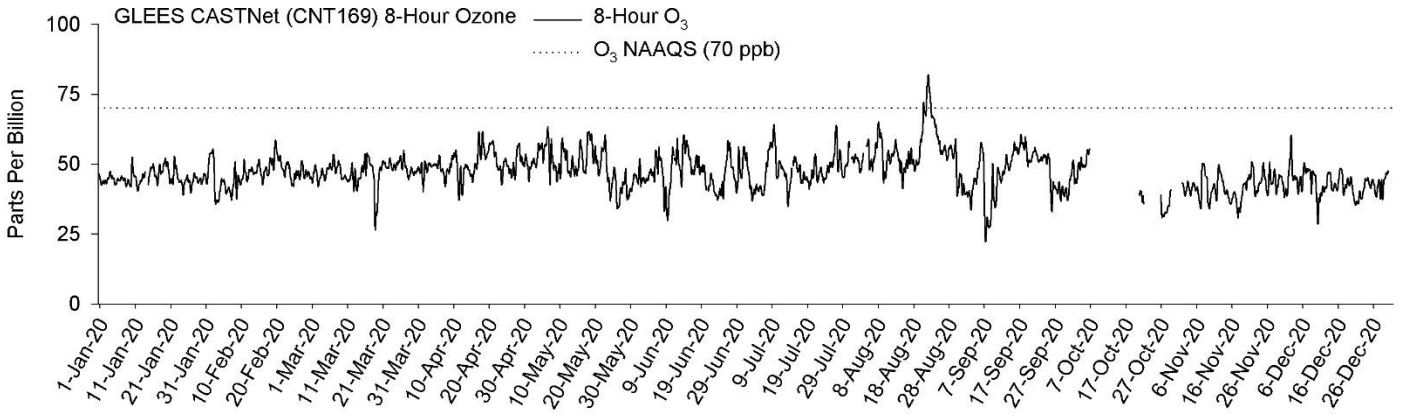
Appendix A. Individual Site Data and Discussion.

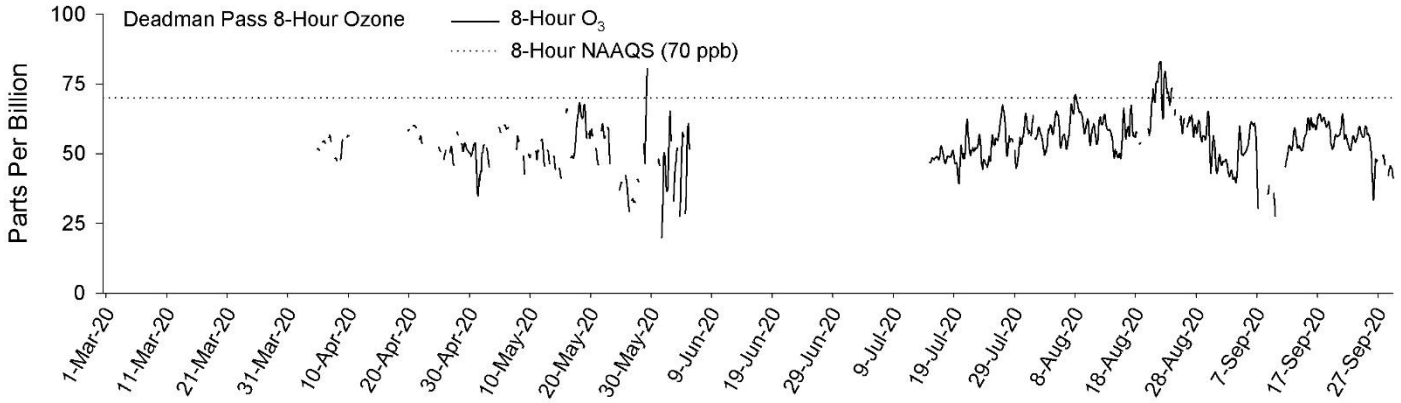
Region 2 Sites.

1. Centennial. Centennial CASTNet experienced a substantial spike in ozone during the peak growth periods of the large California fires, and may also have been affected by smoke from the Cameron Peak fire. Data collection at the site was interrupted in October by the Mullen Fire. This very large fire forced the evacuation of CASTNet, NADP and AmeriFlux equipment from the Glacier Lakes Ecosystem Experiments Site. Fortunately, the fire did not reach the site and the equipment was reinstalled after a three-week gap in data collection. Highest impacts of the nearby Mullen fire were not observed due to the shutdown.



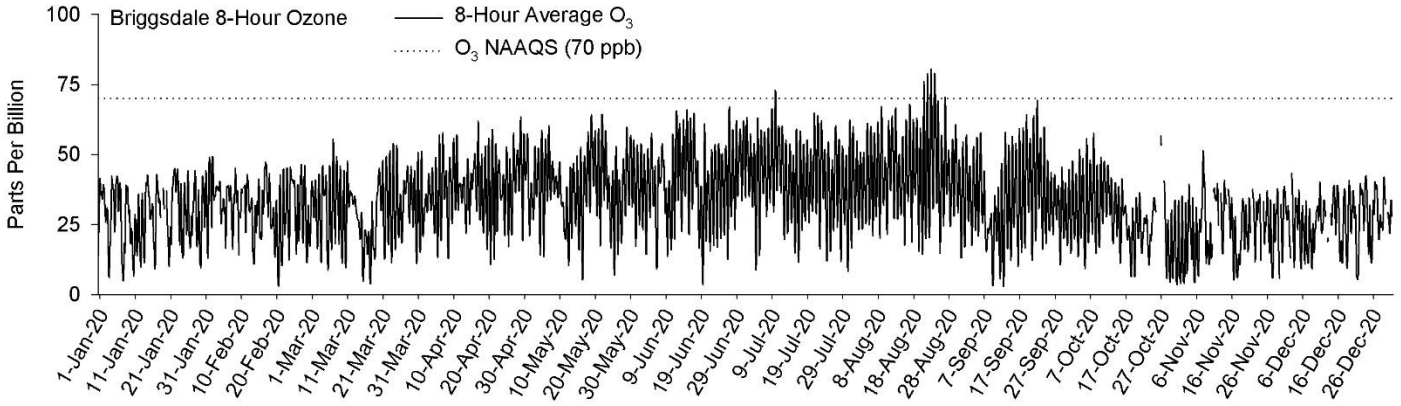
Average ozone at Centennial was down about 1 ppb on average from 2019, and no major surface ozone event occurred in 2020 outside of the obvious peaks caused by the wildfires. Both peak W126 (9.2 ppm-hr) and MD8 (65.5 ppb) values indicate benign conditions.

2. Deadman Pass. Early onset of data collection at Deadman was partially successful. Valid data were first available on April 4th, but cold temperatures and power supply issues limited the effort. And, on June 6th, the analyzer was damaged by water ingestion, and a new analyzer was later installed. Data collection after analyzer replacement was successful.



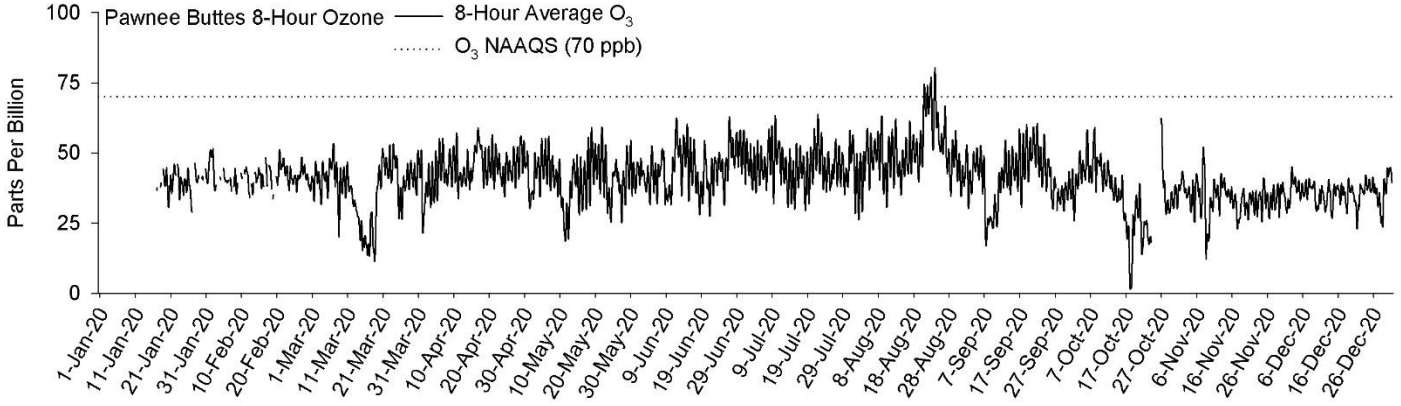
Late-season data (from mid-July through Oct. 1st) indicate a typical summer at Deadman, with daytime values frequently in the upper 60s ppb. The eight-hour average peaked at 83.1 ppb in late August when the site was influenced by multiple large wildfires, particularly Cameron Peak. August-October was the only period during which data were adequate to calculate W126; the figure of 14.1 ppm-hr indicates the continued possibility of ozone impact to vegetation.

3. Briggsdale. Ozone at Briggsdale did not exhibit substantial differences from most previous years, although the average daytime figure was 1.1 ppb greater than 2019. Several brief events that approached or exceeded 70 ppb (8-hour average) occurred in late spring and early summer. Emissions from California fires and the Cameron Peak fire produced a five-day period (21-25 Aug) where ozone exceeded 70 ppb for most of the afternoon hours. This was among the most sustained periods of elevated ozone on the network.



Overnight titration of ozone with NO_x again characterized the site, with overnight concentrations averaging 24.8 ppb. Vegetation exposure was significant at this site in 2020, peaking at 15.7 ppm-hr (June-August). Briggsdale's current 3-year average of MDA8 is now 70.1 ppb, exceeding the NAAQS. The influence of transient high readings on ozone loading is especially evident when one considers the annual daytime average, which at 42.2 ppb, is the lowest on the network.

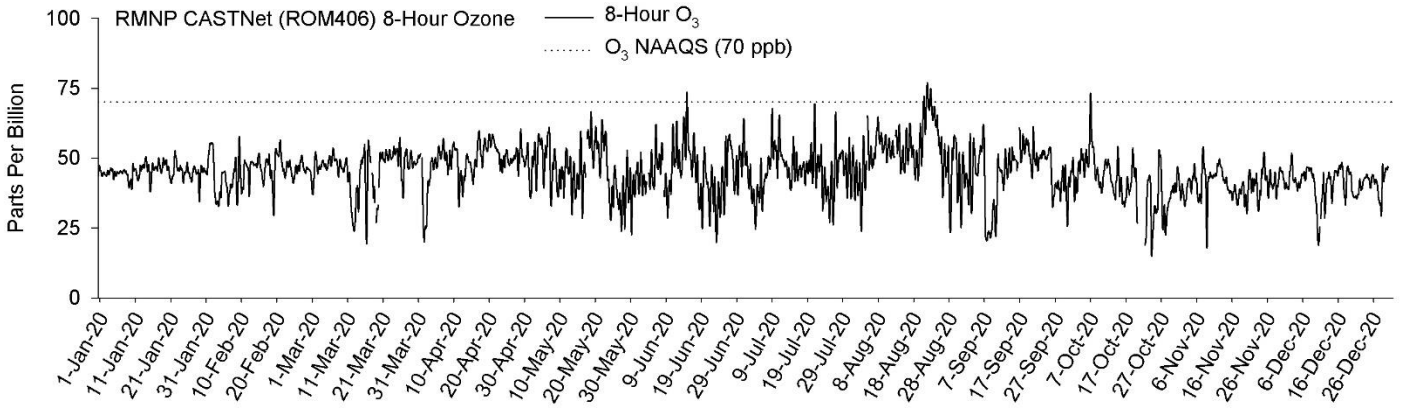
4. Pawnee Buttes. The eastern of the two sites on the Pawnee National Grassland, Pawnee Buttes exhibited a slightly higher daytime ozone average than Briggsdale, but, aside from late August, had no events whose 8-hour averages exceeded 70 ppb. The late-August event during the wildfires had peak values lower than Briggsdale, with a similar duration. A second, shorter event in October due to the East Troublesome Fire emissions, was more noticeable at Pawnee Buttes than farther west at Briggsdale.



The value of W126 is strongly influenced by high-ozone events. Although Pawnee Buttes experienced higher daytime ozone on average than Briggsdale, its W126, at 11.0 ppm-hr (June-August) is substantially lower. Ozone impact to vegetation was not significant here in 2020.

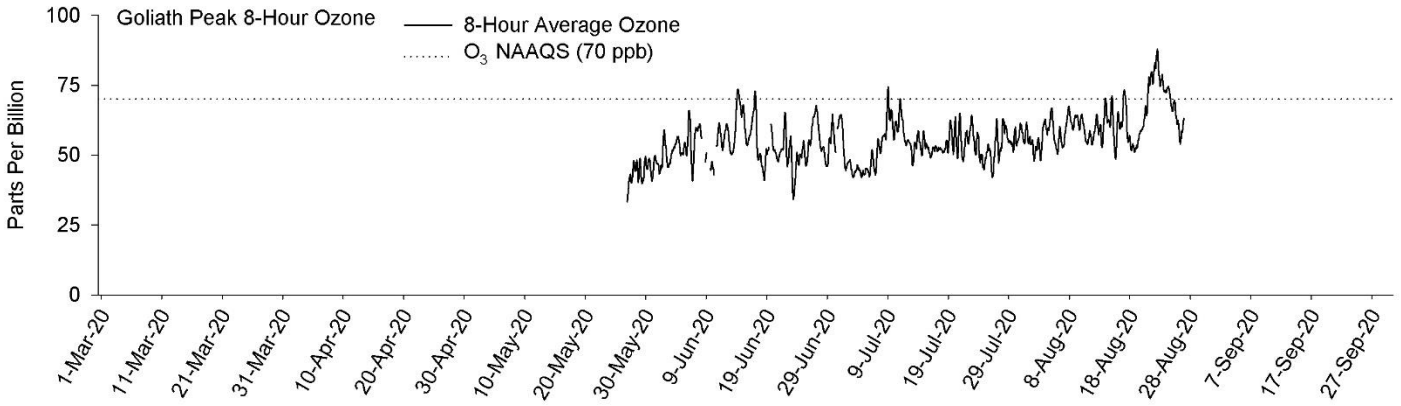
5. RMNP CASTNet. Seemingly at ground zero for Colorado Front Range fire impacts, the RMNP CASTNet station had an eventful year. Several short-duration events occurred in late spring through early August, with 8-hour averages in the

high 60s ppb to just over 70. Atmospheric conditions produced a major event in late August here as at all other network stations, with local emissions from the Cameron Peak fire combining with fires in states farther west.



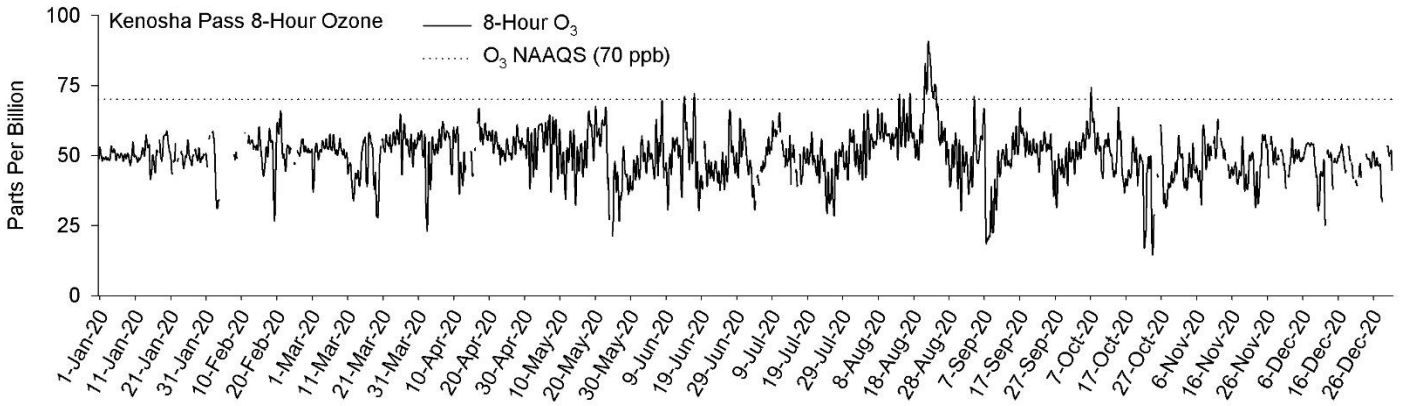
The site was shut down for two days (21-22 October) during the time of greatest danger during the East Troublesome fire, so the greatest impact from the East Troublesome fire was not observed. Annual average values were not significantly different from 2019.

6. Goliath Peak. Upslope from Denver metro-area emissions, Goliath Peak recorded a fourth-maximum MDA8 value over the NAAQS on five days outside the late-August wildfire window. Mid-June and mid-July saw extended periods of elevated ozone. Seasonal data collection terminated at the end of August due to a datalogger memory failure.



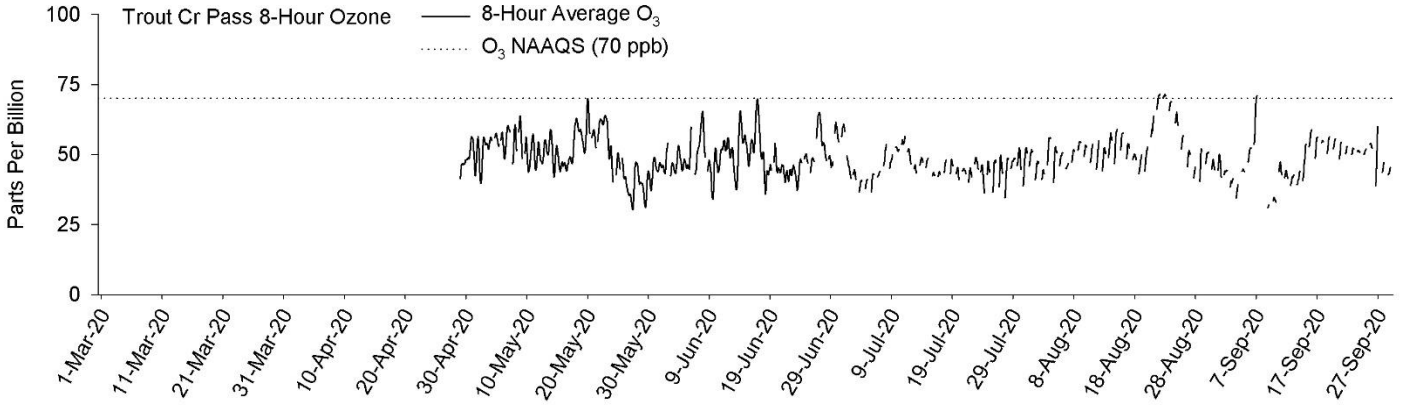
The MDA8 value of 86.2 ppb in late August was second-highest on the network, although this occurred in the state's proposed exception window. However, the three-year MDA8 average of 75.5 ppb remains well above the NAAQS. The W126 value of 17.5 ppm-hr (June-August) was the highest seen on the network. The area should continue to be monitored for signs of vegetation damage.

7. Kenosha Pass. Except during wildfire events, ozone observations at Kenosha Pass were similar to those of 2019. Late-spring peaks over 70 ppb were typical of this high-elevation site, and the 4th-maximum MDA8 value of 71.8 ppb was recorded on August 14th. The three-year MDA8 average of 74.3 ppb is second only to Goliath Peak on the network and puts Kenosha Pass in nonattainment of the NAAQS.



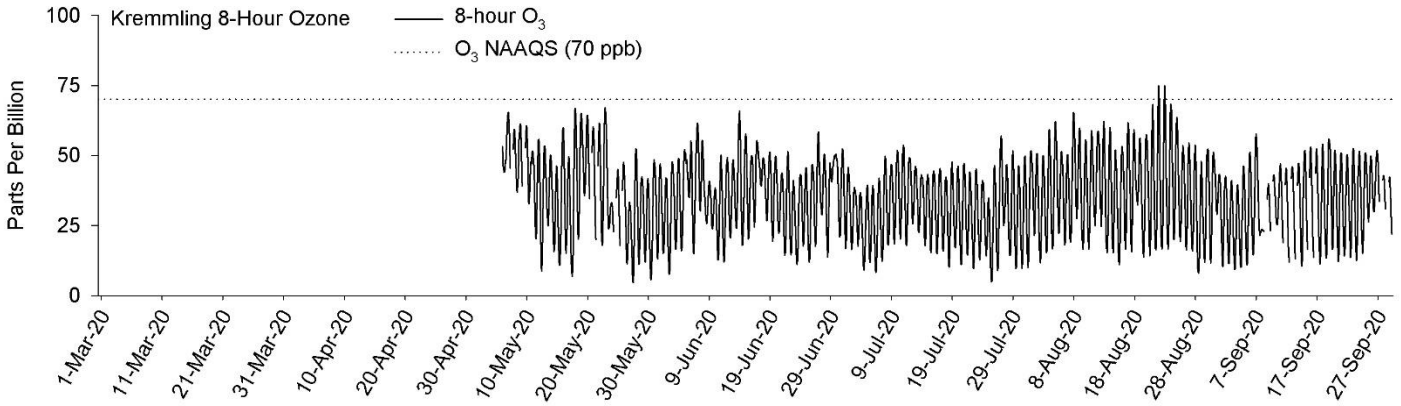
Kenosha's location south of the largest Colorado fires helped attenuate the impacts of the large late-season fires. However, W126 at 17.0 ppm-hr (July-September) is at the low end of values indicative of negative vegetation effects.

8. Trout Creek Pass. Several small wildfires in southwestern Colorado were likely the source of emissions that produced a short early-season period of elevated ozone. This event was attenuated or absent from sites father north and east. Another brief period of high ozone occurred in late spring. Power supply problems limited data collection to the daytime hours after late June. Annual daytime average of 50.3 ppb is 2 ppb lower than that recorded in 2019.



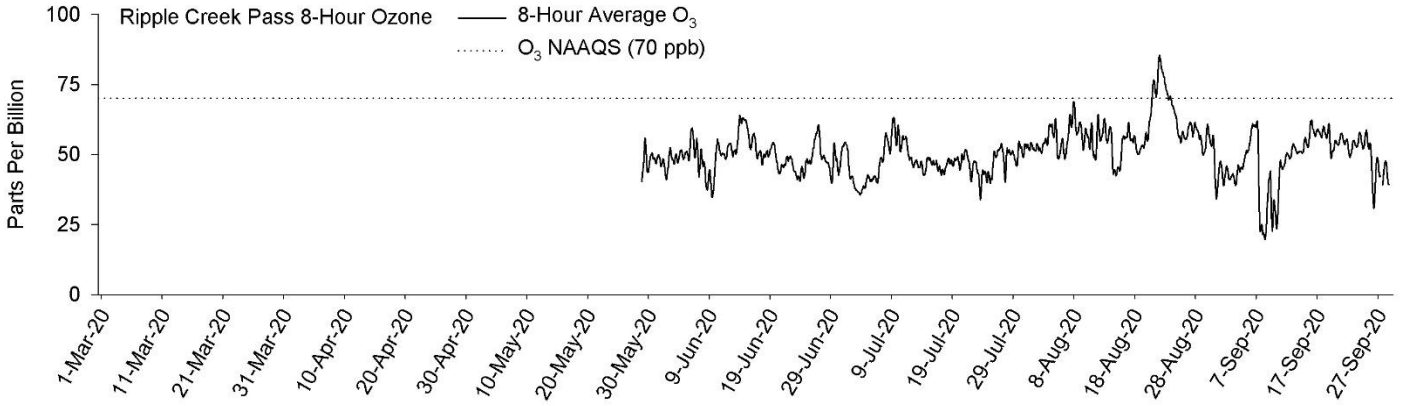
This site experienced the second-least impact from the 2020 fires, with MDA8 peaking at 71 ppb in the fire exemption window; only Shamrock in southwestern Colorado had a lower peak figure. The peak W126 value of 9.0 ppm-hr (June-August) also is one of the lowest on the network.

9. Kremmling. Good air quality remained the rule at this site in 2020, with only the fire-affected event of late August exceeding 70 ppb. Otherwise, seasonal peak was observed in late May, with several days seeing values in the mid-60s ppb. Annual average ozone figures remain very similar to recent years.



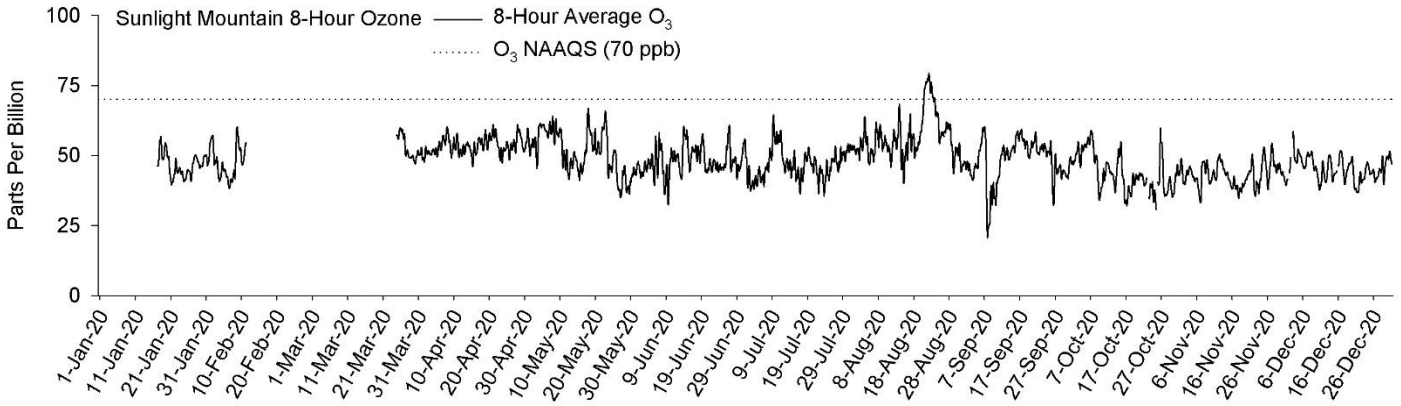
Overnight titration from Kremmling's "urban" NO_x sources greatly attenuate ambient ozone, with early-morning figures in the single digits ppb. The highest three-month W126 of 8.1 ppm-hr is also among the lowest observed.

10. Ripple Creek Pass. Near the north boundary of the Flat Tops Wilderness, this site normally experiences low ambient ozone, and 2020 was no exception. Daytime averages hovered consistently around 50 ppb throughout the spring and much of early summer. The wildfire-influenced peak during late August featured readings over 60 ppb for 112 consecutive hours, but otherwise ozone observations were very similar to those of previous years.



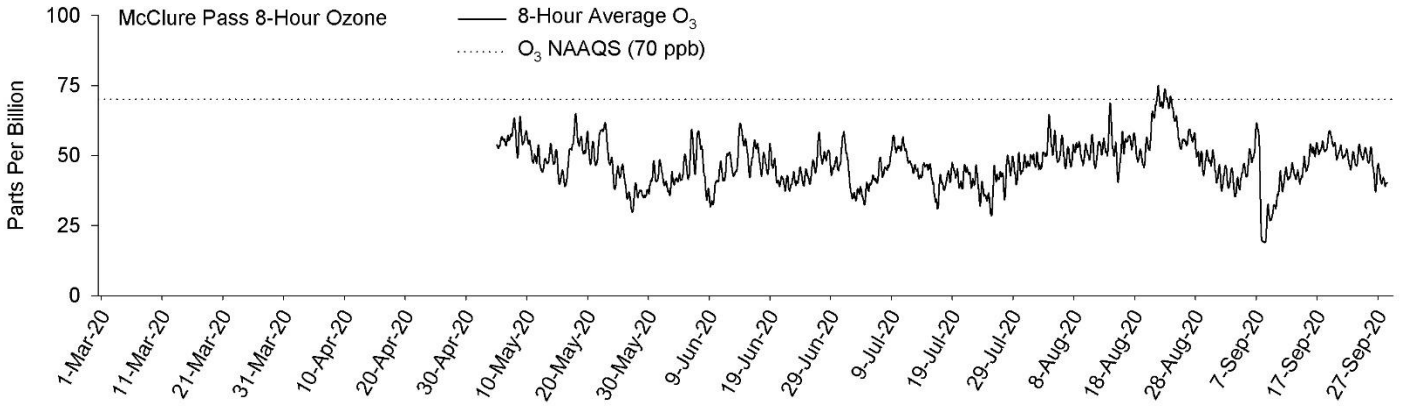
Ripple Creek's three-year average of MDA8, at 63.8 ppb, is the lowest on the network. However, the extended period of exposure pushed the W126 value to 12.1 ppm-hr (July-September), an indication of how these types of events can potentially impact vegetation even in places with otherwise low exposure.

11. Sunlight Mountain. The trend at Sunlight Mountain has been toward lower ozone for several years, and 2020 continued the pattern. No observations outside of the late-August wildfire window exceeded 70 ppb, and the daytime annual average was 0.5 ppb lower than that of 2019. The three-year MDA8 average, influenced by the high figures of 2018, remains below the NAAQS at 69.7 ppb.



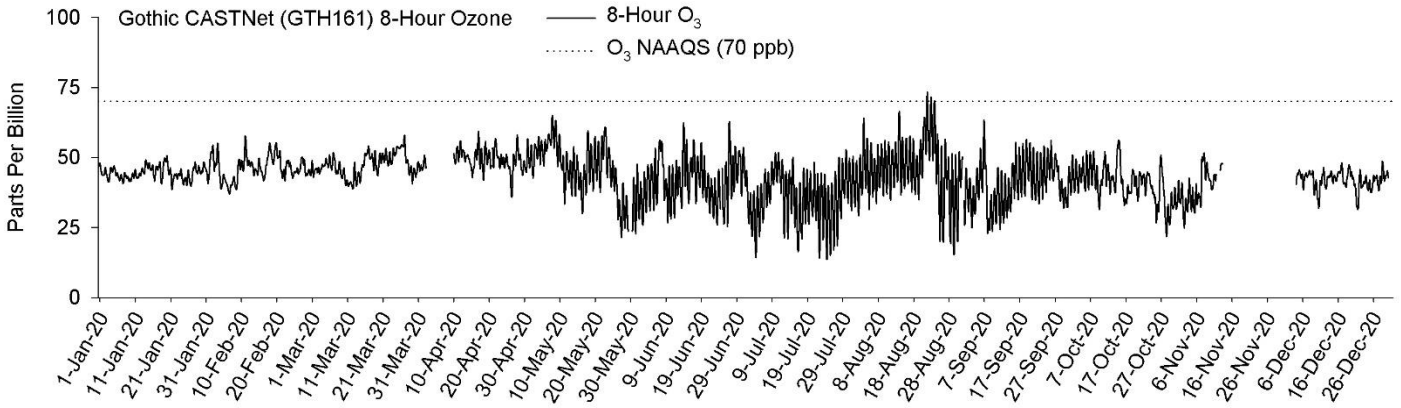
No significant ozone impacts are likely to be occurring at this site at present, with peak daytime W126 of 9.9 ppm-hr (July-September). However, past years have seen considerably higher numbers, and warrant continued attention to the potential for effects.

12. McClure Pass. Like Ripple Creek, this site is relatively remote from urban-source ozone precursors and has consistently ranked among the network's best. Only the late-August wildfires produced readings over 70 ppb, and then only for a relatively brief period. Daytime average ozone was down 0.9 ppb from 2019, continuing a long-term declining trend. The frontal passage of the September storm event was particularly dramatic at this site.



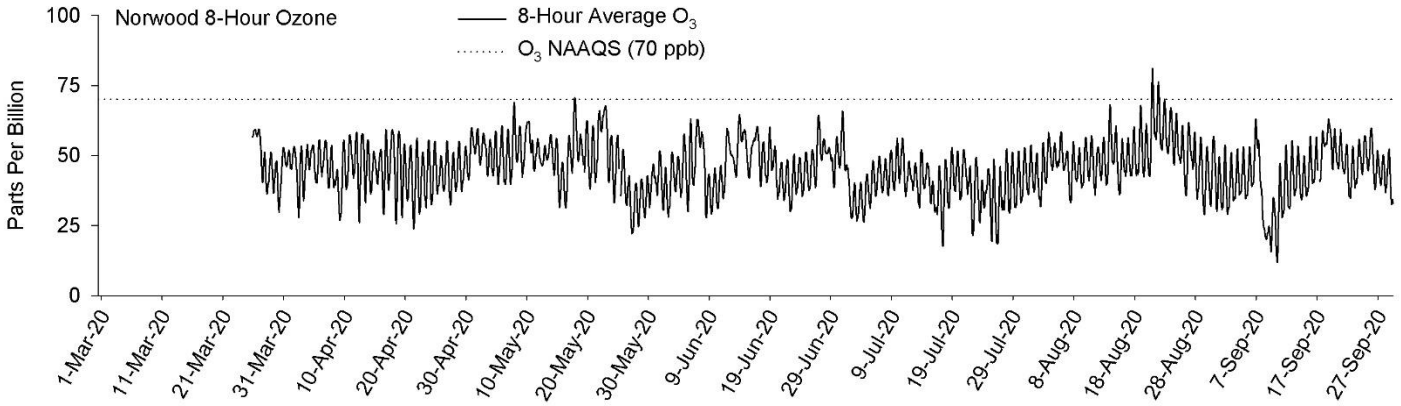
At 8.7 ppm-hr (July-September), McClure experiences no significant ozone impact. The three-year average of MDA8, at 67.6 ppb, remains well below the NAAQS.

13. Gothic CASTNet. Gothic, like the other three sites in the mountains of central Colorado, was relatively isolated from the effects of wildfires, and continued its long-term decline in ambient ozone. The daytime average for 2020, at 46.9 ppb, is 1.3 ppb lower than 2019. Only a few days experienced readings in excess of 70 ppb, and those during the late-August wildfire period.



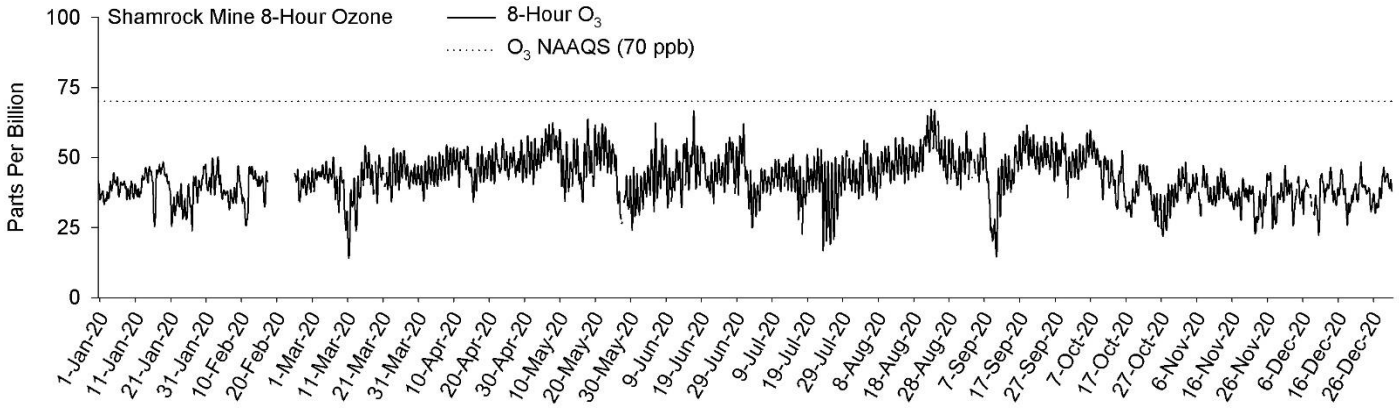
Vegetation hazard at Gothic is very low, with daytime W126 peaking this year at only 7.8 ppm-hr (June-August). The three-year MDA8 average of 66.4 ppb places it well below the NAAQS and among the least-impacted sites on the network.

14. Norwood. This site was somewhat unusual in 2020 with a mid-May max MDA8 (70.5 ppb) and a daytime average figure higher than in 2019 (increase of 3 ppb to 51.7). However, surface ozone remained fairly benign and the site is in no danger of exceeding the NAAQS at present (3-year MDA8 average of 66.2 ppb). No periods of extended ozone exposure occurred outside the peak wildfire period.



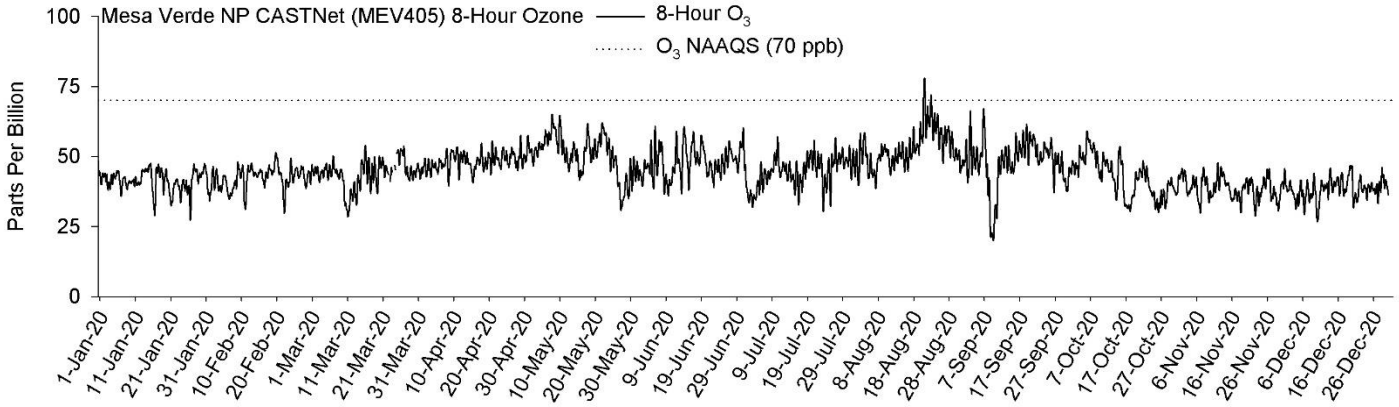
The site was also unusual in having an early-season daytime W126 peak (11.4 ppm-hr, April-June), the only site besides Shamrock to have an early peak. Wildfires had less influence here than at most other sites on the network.

15. Shamrock. The smaller impact of wildfires in southwest Colorado was evident at Shamrock where, alone among network sites, no 8-hour averages exceeded 70 ppb. Although the late-August emissions influx is evident, its magnitude was considerably lower than at sites further north.



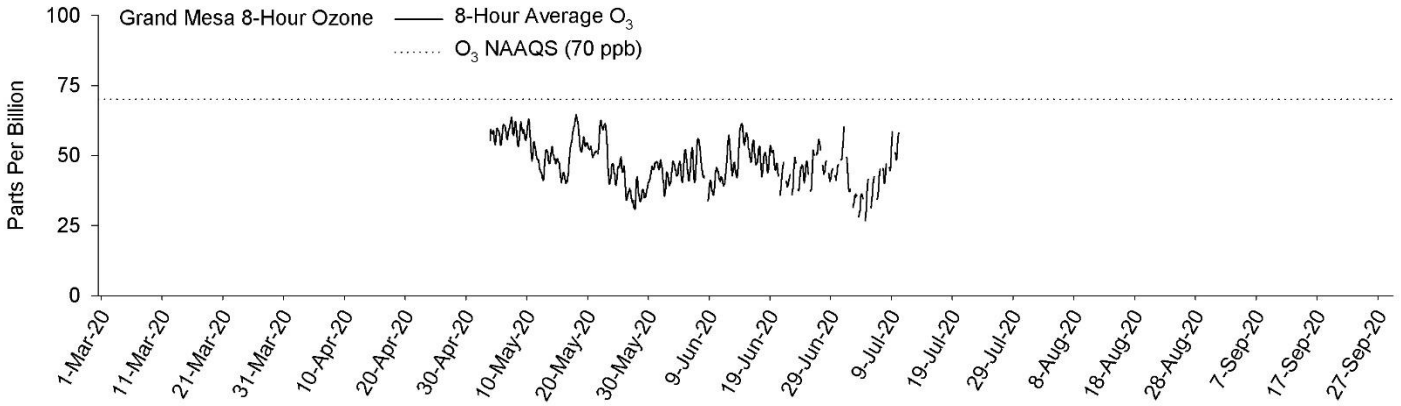
Ozone loading continues to be of little consequence, with three-year MDA8 average at 64.5 ppb. Daytime W126 is similarly low, at 8.5 ppm-hr (April-June).

16. Mesa Verde National Park CASTNet. Like the other three sites in the Four Corners area, Mesa Verde experienced little ozone impact in 2020. This CASTNet site's monitor recorded only a few readings over 70 ppb, and eight-hour averages were over 60 ppb on only 18 days. Fire emissions in August were more evident here than at Norwood and Shamrock, although of fairly short duration.



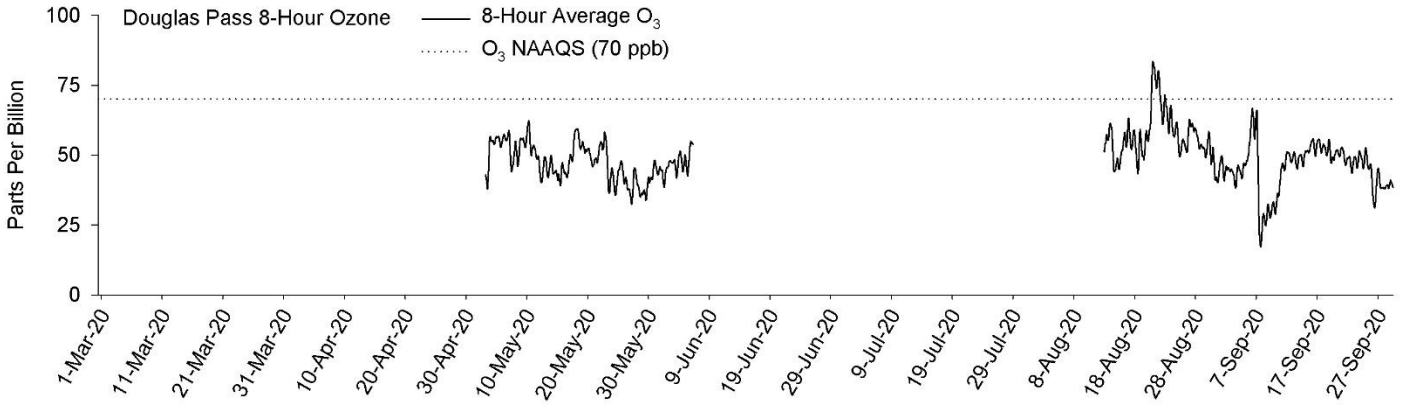
Ozone remains consistently low and impacts insignificant at Mesa Verde. Daytime W126 peaked at 10.0 ppm-hr for the July-September period, and the annual daytime ozone average was down 1.3 ppb over 2019. The site is solidly within attainment, with the three-year average MDA8 at 67.3 ppb.

17. Grand Mesa. This site was well-positioned to assess emissions from the massive Pine Gulch fire in August. Regrettably, the analyzer experienced uncorrectable calibration drift and did not collect valid data during the fire.



Of the available data, none showed signs of excessive ozone loading. A new analyzer will be deployed at the site in 2021.

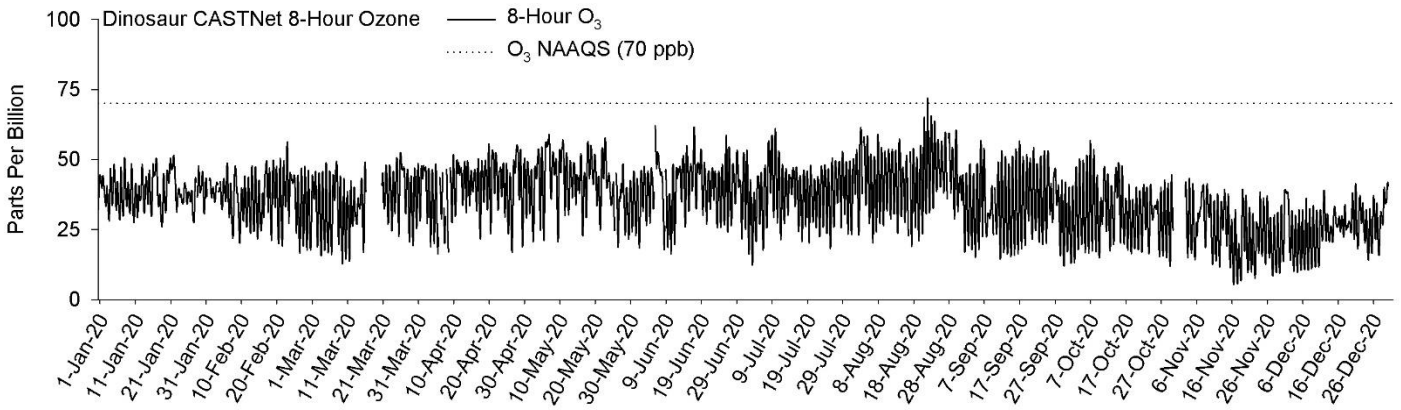
18. Douglas Pass. An instrument malfunction also precluded data collection at Douglas Pass during the most active phase of the Pine Gulch fire, and fire-related road closures prevented the operator from replacing the instrument until safe travel was possible. Ozone exceeded 70 ppb only during the late-August wildfires, although that figure was almost certainly exceeded in early August when the Pine Gulch fire burned to within 2 km of the site.



Ozone exposure for vegetation could not be assessed for 2020 due to the paucity of data.

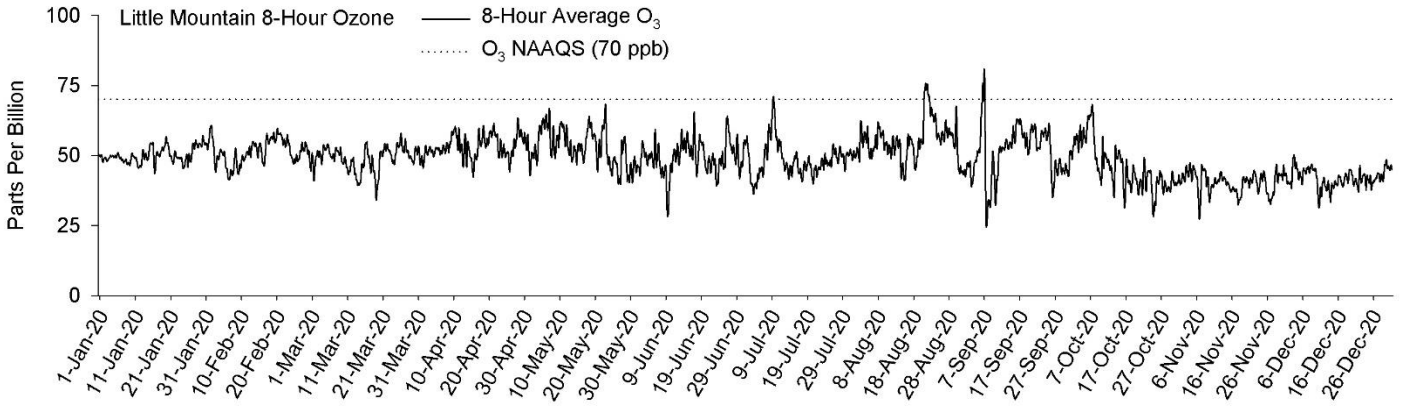
Region 4 Sites.

19. Dinosaur National Monument CASTNet. Once a hotspot for ozone, especially in winter, the Dinosaur CASTNet has seen consistently lower ozone loading in recent years. The annual average of 42.9 ppb at this low-elevation site is second-lowest on the network. Concentrations rarely exceeded 60 ppb (107 hr total in 2020) and were only modestly affected by the August wildfires.



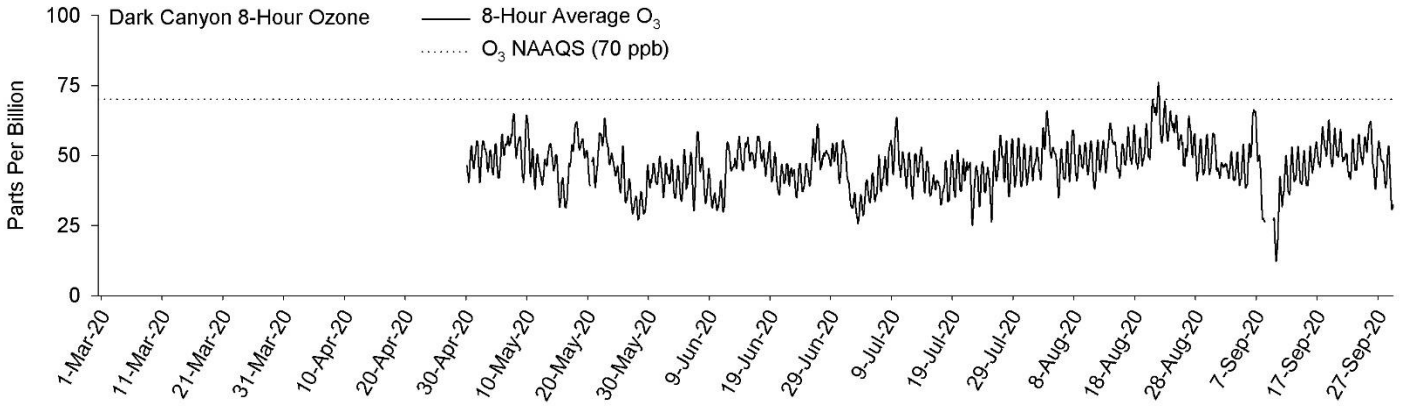
No wintertime spikes of ozone were noted this year. Daytime peak W126, at 7.5 ppm-hr, indicates the lowest vegetation impact of all sites.

20. Little Mountain. This site saw a decrease in daytime annual average of 2.4 ppb over 2019, a significant drop. The event of early June was more evident here than at many northern sites, but no extended periods of elevated ozone occurred outside of wildfire-influenced events. The September pre-frontal ozone spike was especially emphatic here, and the site actually experienced its highest ozone of the year on September 7th. Ozone exceeded 60 ppb for 30 continuous hours on this date and averaged 78 ppb for that period.



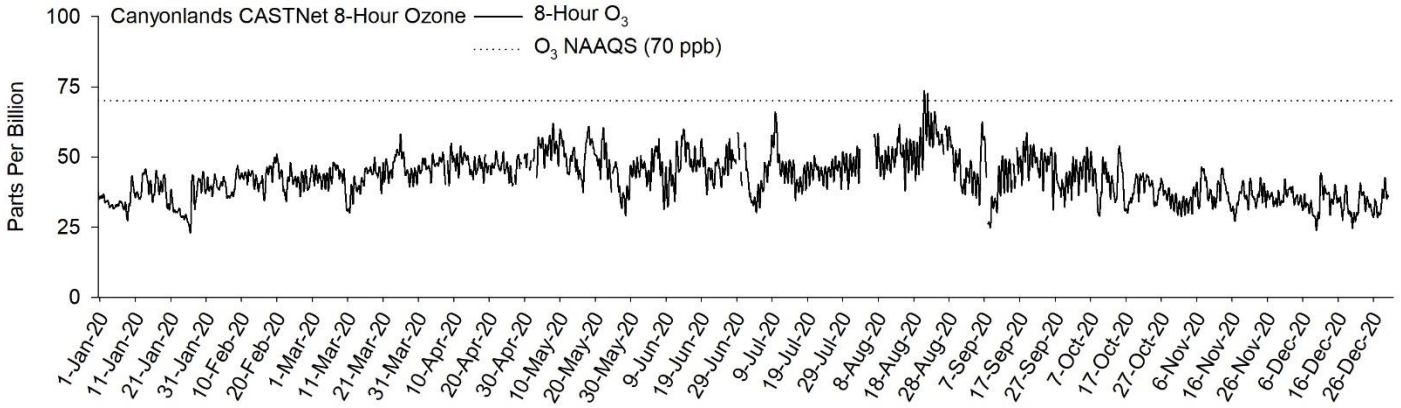
Although Little Mountain's 3-year MDA8 average remains over the NAAQS (71.5 ppb), this year's 4th-max value (64.7 ppb) is nearly 10 ppb lower than the 4th-max of 2018. The July-September figure for daytime W126, 11.0 ppm-hr, does not indicate significant impact.

21. Dark Canyon. Largely free of wildfire impact, Dark Canyon experienced a calm year for ozone, a prevailing theme for the Four Corners area sites. The early June event was not detected at Dark Canyon, probably because prevailing winds carried the smoke from the southwest Colorado fires away from the site. Annual daytime average ozone was not significantly changed from 2019.



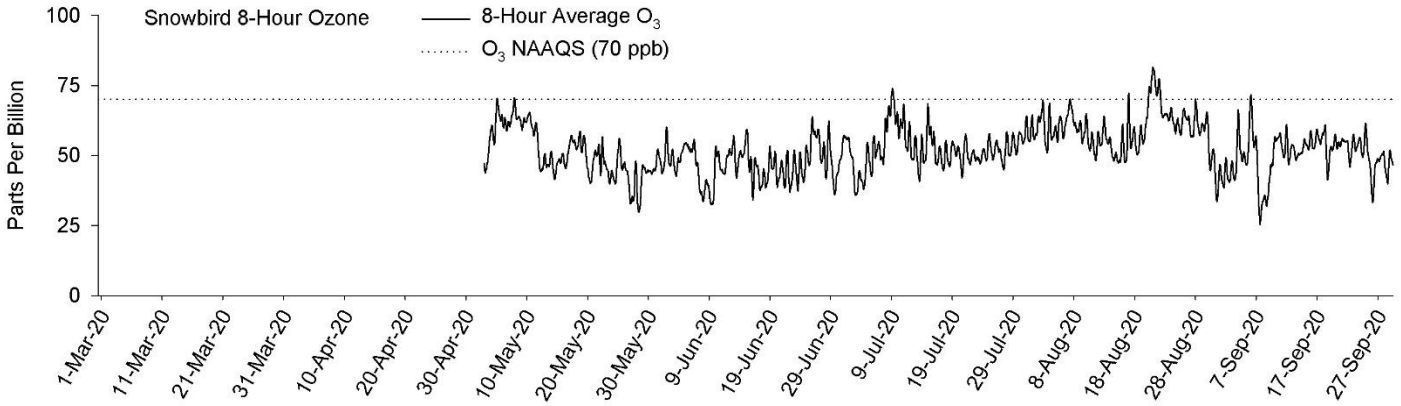
Three-year average MDA8 (64.4 ppb) and W126 (10.7 ppm-hr, July-September) both remain well below hazard thresholds.

22. Canyonlands CASTNet. As at Dark Canyon, about 100 km to the south, no events of great consequence occurred at this site in 2020. The most notable event outside of the late-August wildfire effects was a brief spike in early July, which may have been the result of the Canal fire to the west of the park, or fires in southeastern Nevada. Otherwise, as the annual daytime average of 43.6 ppb indicates, the year was fairly benign.



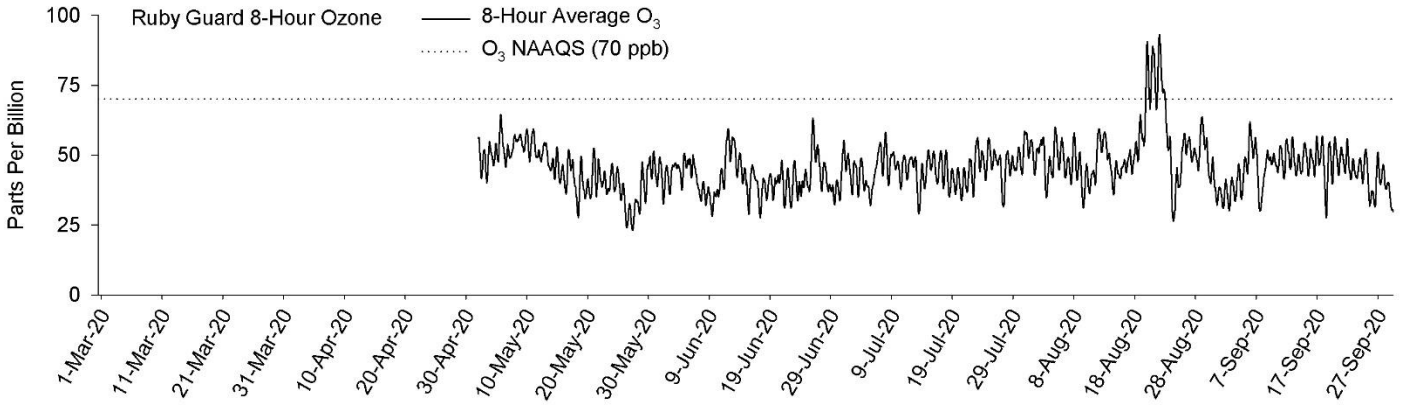
Daytime peak W126 of only 8.8 ppm-hr indicates no significant vegetation hazard at the site.

23. Snowbird. This site again ranked among the most-impacted, second only to Goliath Peak in most metrics. Average daytime ozone, at 53.5 ppb, was not significantly changed from 2019. Prevailing winds may have brought smoke from the Canal fire in south-central Utah or several fires in southeastern Nevada in early July, causing a short-duration event. Early-season peaks near 70 ppb were likely the result of transport of urban-source precursors to the site. Snowbird recorded the longest duration of high ozone during the late-August wildfire peak: ozone was consistently above 60 ppb during daytime for a 207-hour period.



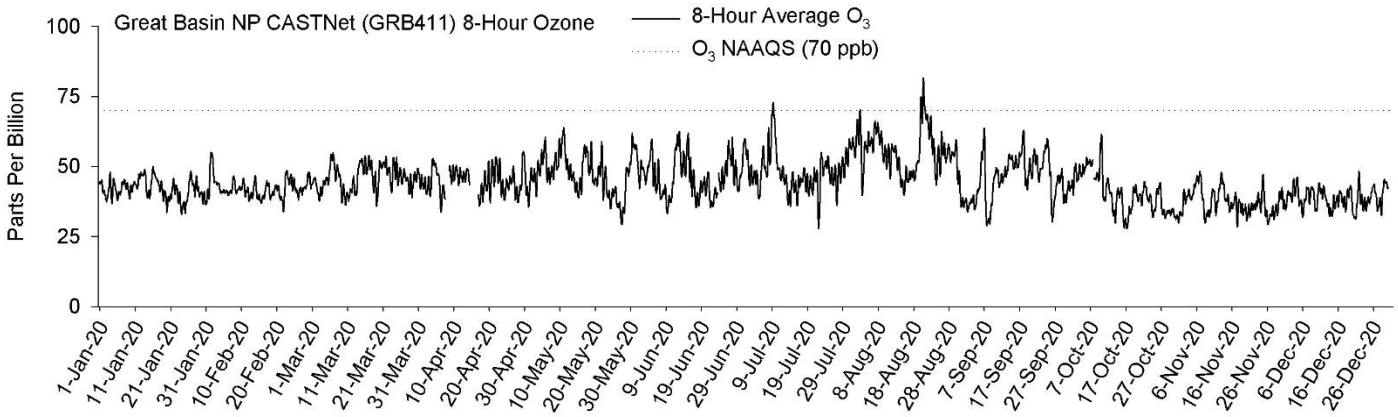
At 17.0 ppm-hr (July-September), the daytime peak W126 figure at Snowbird indicates a continuing potential hazard to vegetation. No values below 15.3 ppm-hr have been reported here since 2014. The site is within the Wasatch Front nonattainment zone, and its 3-year MDA8 average of 73.8 ppb is indicative of the area's difficulties in reducing surface ozone pollution.

24. Ruby Guard. This is the northwestern-most site on the network, and it was thus the most heavily impacted by the California fire blowup in late August. An 84-hour period during this time showed 1-hour averages over 60 ppb, peaking at 100.0 ppb on August 22nd. The remainder of the monitoring season, however, saw values much closer to historical observations. This year's 4th-maximum MDA8 was only 61.8 ppb, second-lowest on the network. At 48.4 ppb, the daytime average was identical to 2019's figure.



No long-term ozone hazard exists at present at this site. This year's maximum daytime W126, at 9.9 ppm-hr, is well below critical levels for vegetation. The three-year average MDA8, at 63.9 ppb, is bettered only by the number from Ripple Creek Pass.

25. Great Basin National Park CASTNet. The early-July event noted at other southwestern sites was also seen at Great Basin, with 8-hour averages peaking just over 70 ppb. Otherwise, values hovered around the annual daytime average of 45.5 ppb, a figure not significantly different from 2019. Non-fire 4th-maximum MDA8 occurred on August 7th at 66.3 ppb. The early September frontal passage affected this site, as it did all others, but the effects were relatively muted.



Precursor emissions from Los Angeles and Las Vegas do not seem to greatly affect this site, with no recent incidences of high ozone loading. Daytime W126 peak (June-August) at 11.0 ppm-hr reflects the low ozone hazard at the site.